10 Rec'd PCT/PTO 25 JAN 2002

FORM PTO-1390 REV. 5-93 US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEYS DOCKET NUMBER **P02,0001** U.S.APPLICATION NO. (if known, see 37 CFR 1.5) 10/048052
INTERNATIONAL APPLICATION NO. **PCT/DE00/02438**	INTERNATIONAL FILING DATE **25 JULY 2000**	PRIORITY DATE CLAIMED **27 JULY 1999**

TITLE OF INVENTION

COMPUTED TOMOGRAPHY DEVICE WITH MULTI-LINE DETECTOR SYSTEM (AS AMENDED)

APPLICANT(S) FOR DO/EO/US

THOMAS FLOHR and GEORGE OHNESORGE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ☒ A copy of International Application as filed (35 U.S.C. 371(c)(2)) - drawings attached.
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2) -

7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.

8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). **(unexecuted)**

10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report)**.

12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included. (Separate envelope)

13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.

14. ☒ A substitute specification, including red-lined version

15. ☐ A change of power of attorney and/or address letter.

16. ☒ Other items or information:
    a. ☒ Request for Approval of Drawing Changes
    b. ☒ Submission of Drawings for Publication
    c. ☒ Express Mail Label EL 843741616US dated January 25, 2002

JC13 Rec'd PCT/PTO 25 JAN 2002

U.S.APPLICATION NO. (if known, see 37 C.F.R. 1.5) 10/048052	INTERNATIONAL APPLICATION NO. PCT/DE00/02438	ATTORNEY'S DOCKET NUMBER P02,0001

	CALCULATIONS	PTO USE ONLY
17. ☒ The following fees are submitted: **BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5):** Search Report has been prepared by the EPO or JPO .... $1040.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482)$890.00 No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) .... $740.00 Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO .... $710.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	7 - 20 =	0	X $18.00	$	
Independent Claims	1 - 3 =	0	X $ 84.00	$	
Multiple Dependent Claims			$280.00 +	$	
TOTAL OF ABOVE CALCULATIONS =				$890.00	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)				$	
SUBTOTAL =				$890.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$890.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property +					
TOTAL FEES ENCLOSED =				$890.00	
				Amount to be refunded	$
				charged	$

a. ☒ A check in the amount of $890.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ____________ in the amount of $ _________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 501519 . A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Steven H. Noll
SIGNATURE

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Steven H. Noll
NAME

28,982 (Registration No.)

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

AMENDMENT "A" PRIOR TO ACTION AND SUBMISSION OF SUBSTITUTE SPECIFICATION

APPLICANTS:	Flohr et al.
ATTORNEY DOCKET NO.	P02,0001
INTERNATIONAL APPLICATION NO:	PCT/DE00/02438
INTERNATIONAL FILING DATE:	July 25, 2000
INVENTION:	"CT DEVICE WITH A MULTI-LINE DETECTOR SYSTEM"

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Applicants herewith amend the above-referenced PCT application as follows, and request entry of the Amendment prior to examination in the United States National Examination Phase.

IN THE TITLE:

Please cancel the present title and substitute the following title therefor:

--"COMPUTED TOMOGRAPHY DEVICE WITH A MULTI-LINE DETECTOR SYSTEM"--.

IN THE SPECIFICATION:

Please enter the substitute specification submitted herewith pursuant to 37 C.F.R. §1.125(b). The substitute specification merges the original PCT application and substitute pages 2 and 2a. A marked-up copy of the substitute specification, showing all of the changes made therein, is also submitted herewith. The substitute specification does not add any new matter.

IN THE DRAWINGS:

Please amend each of Figures 1, 2 and 3 as shown on the drawing copies marked in red, attached to the Request for Approval of Drawing Changes filed simultaneously herewith.

IN THE CLAIMS:

On page 12, cancel "Patent Claims" and substitute:

--**WE CLAIM AS OUR INVENTION**-- therefor.

Cancel claims 1-6 and substitute the following claims therefor:

7. A computed tomography device comprising:

a radiation source which emits a radiation beam from a focus, at least said focus being displaceable relative to a system axis to scan an examination subject with said radiation beam from a plurality of projection angles;

a radiation detector on which said radiation beam is incident after passing through said examination subject, said radiation detector being formed by a plurality of detector elements in rows proceeding substantially perpendicularly to said system axis and columns proceeding substantially parallel to said system axis, each of said detector elements generating an electrical signal corresponding to radiation from said radiation beam incident thereon;

a plurality of electronic elements for reading out said electrical signals from said detector elements, to generate measured values;

the detector elements in a first region of said radiation detector being connected to a larger number of said electronic elements than the detector elements in a second region of said radiation detector comprising a same number of said columns; and

a computer supplied with said measured values for reconstructing an image of said examination subject therefrom.

8. A computed tomography device as claimed in claim 7 wherein the detector elements in at least one of said columns are not connected to any of said electronic elements.

9. A computed tomography device as claimed in claim 7 wherein said computer generates additional measured values from said second region by interpolation of the measured values from the electronic elements connected to the detector elements in said second region.

10. A computed tomography device as claimed in claim 7 wherein said computer generates additional measured values from said second region by extrapolation from the measured values from the electronic elements connected to the detector elements in said first region.

11. A computed tomography device as claimed in claim 7 further comprising a support arrangement adapted to receive said examination subject thereon and a displacement arrangement for producing relative displacement between said radiation beam and said support mechanism along said system axis, with said projections being obtained at successive positions along said system axis.

12. A computed tomography device as claimed in claim 7 wherein said detector elements are detector elements which generate said electrical signals by producing electrical charges due to absorption of said radiation.

13. A computed tomography device as claimed in claim 7 wherein the detector elements in one of said rows have a first length in a direction along said system axis and wherein the detector elements in another of said rows have a second length in said direction along said system axis, said first and second lengths being different.

IN THE ABSTRACT:

The Abstract has been amended as follows:

ABSTRACT OF THE DISCLOSURE

In a CT device with a multi-line detector system, different columns of the detector system can be connected to different numbers of electronic elements in order to read the signals generated in the detector elements. Thus, by using the detector systems, regions of the object to be examined can be scanned with a high resolution, and other regions can be scanned with a lower resolution. A high resolution in regions can therefore be achieved with a simplified and less expensive detector system, which generates a comparatively low data rate and amount of data.

REMARKS:

The present Amendment makes editorial changes in the title, specification, drawings, claims and the Abstract, in order to conform to the requirements of United States patent practice. The cancellation of claims 1-6 in favor of the claims presented herein has been made solely because the amount of bracketing and underlining necessary to conform the original claims to the requirements of United States patent practice would have been unduly burdensome and confusing. No change in claim language in the claims presented herein as compared to the original claims has been made for the purpose of distinguishing any of the claims over the teachings of the prior art of record, and accordingly no change in the claim language between the claims submitted herein and the original claims is considered by the Applicants to be a surrender of any of the subject matter encompassed within the scope of original claims.

Early consideration of the present PCT application is respectfully requested.

Submitted by,

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Attorneys for Applicants.

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE ABSTRACT

Please amend the Abstract as follows:

[Abstract

CT device with a multi-line detector system]

ABSTRACT OF THE DISCLOSURE

In a CT device with a multi-line detector system [(5)], different columns [(7, 7')] of the detector system [(5)] can be connected to different numbers of electronic elements [(13)] in order to read the signals generated in the detector elements [(8)]. Thus, by using the detector systems [(5)], regions of the object to be examined can be scanned with a high resolution, and other regions can be scanned with a lower resolution. A high resolution in regions can therefore be achieved with a simplified and less expensive detector system [(5)], which generates a comparatively low data rate and amount of data.

[Figure 4]

10/048052
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SUBSTITUTE SPECIFICATION

SPECIFICATION

TITLE

"COMPUTED TOMOGRAPHY DEVICE WITH A MULTI-LINE DETECTOR SYSTEM"

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a CT (computed tomography) device of the type having a radiation source which, in order to scan an object to be examined, can be displaced relative to a system axis and emits a beam of radiation, which strikes a detector system formed by an array of lines and columns of detector elements, the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer, which uses them to calculate images of the object to be examined, the signals generated in the detector elements by radiation being supplied to electronic elements to be read and amplified, the number of detector elements of the detector system exceeding the number of electronic elements.

Description of the Prior Art

CT devices are known which have a radiation source, for example an X-ray tube, which directs a collimated, pyramidal beam of radiation through the object to be examined, for example a patient, onto a detector system formed by a number of detector elements. The radiation source and, depending on the design of the CT device, the detector system also are mounted to a gantry, which rotates around the object to be examined. A mounting device for the object to be examined can be displaced or moved along the system axis relative to the gantry. The position from which the radiation beam passes through the object to be examined, and the angle at which the beam of radiation passes through the object to be examined, are varied continually as a result of the rotation of the gantry. Each detector

element in the detector system that is affected by the radiation produces a signal which constitutes a measure of the overall transparency of the object to be examined for the radiation originating from the radiation source on its path to the detector system. The set of output signals from the detector elements of the detector system, which is obtained for a specific position of the radiation source, is referred to as a projection. A scan is formed by a set of projections, which have been obtained at various positions of the gantry and/or various positions of the mounting device. During one scan, the CT device assumes a large number of projections, in order to be able to build up a two-dimensional sectional image of a layer of the object to be examined. With a detector system constructed from an array of lines and columns of detector elements, a number of layers can be recorded at the same time.

German OS 195 02 574 discloses a CT device of the type mentioned in the introduction having a multi-line detector system, in which, in order to save cost and in order to limit the data rates, the read electronics connected downstream of the detector elements does not have an electronic element for each detector element. Instead, the number of detector lines exceeds the number of lines of electronic elements. Each line of electronic elements can be associated with a number of detector lines via multiplexers and summers.

In this known CT device, a disadvantage is that, as a result of connecting adjacent detector lines together, the thickness of the layers recorded increases, and therefore the resolution in the z-direction is decreased. Another disadvantage is that each detector line is not connected to a line of electronic elements, and therefore it is not possible for the entire detector width in the z-direction to be used for data acquisition.

German OS 198 35 873 discloses a CT device of the type mentioned in the introduction, in which the number of detector elements exceeds the number of electronic elements and, therefore, region by region, a number of detector elements of a detector line are coupled, i.e., are connected to one

electronic element, with the coupling of detector elements being omitted in the central region of the detector lines.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a CT device of the type mentioned in the introduction wherein, in spite of a reduced number of electronic elements, as compared with the number of detector elements, a high resolution can be achieved with the detector system and, nevertheless, a high number of individual layers can be recorded at the same time.

According to the invention, this object is achieved by a CT device having a radiation source which, in order to scan an object to be examined, can be displaced relative to a system axis and emits a radiation beam, which strikes a detector system formed by an array of lines and columns of detector elements, the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer, which uses them to calculate images of the object to be examined, signals generated in the detector elements by radiation being supplied to electronic elements to be read and amplified, the number of detector elements of the detector system exceeding the number of electronic elements, and wherein a region of detector columns including at least one detector column can be connected to a larger number of electronic elements, in order to read out the detector elements from this region, than is a different region having the same number of detector columns.

The CT device according to the invention therefore not only has the advantage that the detector system can be implemented more simply and less expensively by means of the number of electronic elements being reduced with respect to the number of detector elements, but also, therefore, region by region a larger number of layers can be recorded at the same time than in the case of detector systems with a reduced number of electronic elements according to the prior art.

Whereas in known CT devices, adjacent detector elements can if required be connected together line by line, and each detector column is associated with a permanently predefined number of electronic elements, the detector system according to the invention can be divided into regions with a different resolution both in the z-direction and in the φ-direction. To this end, different detector columns of the detector system according to the invention can be connected to different numbers of electronic elements. If, for example, a CT device according to the prior art has an 8-line detector system with four lines of electronic elements, then each detector column of the detector system is connected to a maximum of four electronic elements. compared to this, a CT device according to the invention, likewise having an 8-line detector system, permits specific detector columns to be connected, for example, to six electronic elements and other detector columns to be connected only to two electronic elements per detector column. A suitable arrangement of multiplexers and summation elements between the detector elements and the electronic elements permits a largely random interconnection of detector elements and the assignment of individual detector elements or interconnected detector elements to individual electronic elements.

A region of the detector system of the CT device according to the invention whose detector columns are assigned an increased number of electronic elements can, for example, be the especially relevant central region of the detector system. Outside the central region, correspondingly fewer measured values are formed as a result of detector elements being combined or not being taken into account. Given the same overall z-length of the collimated layer over the entire detector, many thin individual layers are in this way obtained in one region, but a few wide individual layers in another region. Therefore, in the one region, the number of effective lines, and therefore the resolution in the z-direction, is increased, without additional electronic elements being required for this purpose. In addition, the data

rates and amounts of data that can be generated by the detector system do not change with respect to a known detector system having a reduced number of electronic elements.

In the CT device according to the invention, the object to be examined can fill the entire measurement field, as hitherto. The object to be examined is merely scanned with a higher resolution in one region than in another region. If the object to be examined fills only a portion of the measurement field as, for example, in the case of examinations of internal organs, the head or the extremities of a patient, then the electronic elements of the detector system according to the invention can be connected to the detector elements so that all the electronic elements are assigned to the relevant region of the detector system, and the edge regions of the detector system, which cannot contribute any measured values to the objects to be displayed, are not assigned any electronic elements. As a result of the simultaneous recording of many thin individual layers, this also leads to an improved resolution with a simultaneous saving in time and costs.

In an embodiment of the invention missing measured values from a region with low resolution are interpolated from the measured values obtained from this region, or missing measured values from a region with a low resolution to be extrapolated from measured values from a region with a high resolution. The values formed in this way, together with the measured values, can then be supplied to a conventional CT multi-line image reconstruction.

Therefore, in this variant, known software can be used in the image reconstruction, which limits the effort and the costs which have to be applied in connection with the creation of the software for a CT device.

Larger volumes of an object to be examined are normally registered by means of sequential scanning or spiral scanning. The CT device according to the invention can advantageously be used for both types of scan.

In the case of sequential scanning, the data are recorded during a rotational movement of the gantry, while the object to be examined is located in a fixed position, and therefore a specific number of planar layers are scanned. In order to scan the following layers, the object to be examined is moved into a new position relative to the gantry. This procedure is continued until the volume defined before the examination has been scanned.

In the case of spiral scanning, the gantry with the X-ray radiation source rotates around the object to be examined, while the mounting table and the gantry are displaced continuously relative to each other along a system axis. The radiation source therefore describes a spiral path in relation to the object to be examined, until the volume defined before the examination has been scanned. Images of individual layers are then calculated from the spiral data obtained in this way.

The detector system of the CT device according to the invention may be constructed in a simple and cost-effective way as a modification (retrofit) of conventional detector systems. By means of the arrangement of summation elements and multiplexers between the detector elements and the electronic elements, and the corresponding wiring, the electronic elements are supplied the charges generated by absorption of radiation in the detector elements, to be read and amplified.

In a preferred embodiment of the detector system according to the invention, the length of the detector elements is different in the direction of the system axis (z-direction). In addition to the advantages already mentioned of a detector system according to the invention, this provides the further advantage that, region by region, by means of appropriate interconnection of adjacent detector elements, additional operating modes are therefore possible with this detector system. For example, in the case of an 8-line detector system having the following detector elements which are not equidistant in the z-direction:

5 mm – 2.5 mm – 1.5 mm – 1 mm – 1 mm – 1.5 mm – 2.5 mm – 5 mm

by means of partial insertion of outer detector elements and combination, the following modes can additionally be realized region by region, in which six layers are scanned:

Mode 1: 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm
Mode 2: 1 mm – 1.5 mm – 1 mm – 1 mm – 1.5 mm – 1 mm

DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the basic components of an X-ray computed tomography device constructed and operating in accordance with the present invention.

Figure 2 shows one column in a central region of the detector system of the computed tomography device of Figure 1, showing how the electronic components are associated with the detector elements of the column.

Figure 3 shows one column in a outer region of the detector system of the computed tomography device of Figure 1, showing how the electronic components are associated with the detector elements of the column.

Figure 4 is a plan view of the detector system of the computed tomography device according to Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a CT device which is provided for scanning an object 1 to be examined and which has a radiation source 2, for example an X-ray tube, with a focus 3 from which a pyramidal beam 4 of radiation collimated by a radiation diaphragm (not illustrated) originates, passes through the object 1 to be examined, for example a patient, and strikes a detector system 5.

The latter has an array of parallel lines 6 and parallel columns 7 of detector elements 8. The radiation source 2 and the detector system 5 form

a measuring system, which can be displaced in the φ-direction around a system axis 9 and can be displaced along the system axis relative to the object 1 to be examined, so that the object 1 to be examined is irradiated at various projection angles and various z-positions along the system axis 9. From the output signals which occur in the process from the detector elements 8 of the detector system 5, a signal processing unit 10 forms measured values, which are supplied to a computer 11, which calculates an image of the object 1 to be examined, which is reproduced on a monitor 12.

In Fig. 1, the detector system 5 is shown only schematically with a number of lines and columns that differs from Figs. 2 to 4. Figures 2 to 4 show that, in the case of the exemplary embodiment described, the detector system has eight lines 6 and twenty-four columns 7, the length of the detector elements 8 in the z-direction, that is to say in the direction of the system axis 9, not being the same for all lines. By means of appropriate insertion and combination of detector lines 6, this geometry is very flexible in the selection of the layer thicknesses to be scanned of the object to be examined. In the middle, each column 7 of the detector system 5 is assigned four electronic elements 13 to read out and amplify the charges generated in the detector elements 8 by the absorption of X radiation. The association between an electronic element 13 and one or more detector elements 8 is carried out via summation elements 14 and multiplexers (not illustrated). The signals registered by the electronic elements 13 are supplied to a signal processing unit 10 for further processing.

As Fig. 2 reveals, the eight detector elements 8 of the detector column 7 illustrated, which, according to fig. 4, lies in the central region of the detector system 5 in the φ-direction, are connected to six electronic elements 13, of the central four detector elements, in each case two, combined via a summation element 14, being connected to one electronic element 13. Signals from all the detector elements in this detector column are thus registered and supplied to the signal processing unit 10.

In order on average to achieve the assignment of four electronic elements per detector column, eight detector elements from another detector column 7', shown in fig. 3, are assigned only two electronic elements 13. The detector column 7' in this case lies in the outer region of the detector system 5 in the φ-direction, according to fig. 4.

Measured values which are missing as compared with the detector column 7 according to Fig. 2 are interpolated from the measured values obtained with the detector column 7' and/or extrapolated from the measured values from adjacent detector columns by means of the computer 11. Therefore, for further signal processing, recourse can be made to image reconstruction algorithms already implemented.

Fig. 4 shows the division of the exemplary detector system 5 into eight lines 6 and twenty-four columns 7 of detector elements 8 in each case. If, for example, only a section of the object 1 to be examined is to be examined, for example in order to image internal organs, the head or the extremities of a patient, then given appropriate positioning of the object 1 to be examined in the CT device, one subregion of the detector system 5 is particularly relevant for registering measured values. In the example according to fig. 4, this is assumed to be the central region I of the detector system 5, containing twelve columns 7 of detector elements 8. In order to increase the resolution in this particularly relevant measurement region, the detector columns 7 according to fig. 2 are each connected to six electronic elements 13. In order to compensate, the columns 7 from the outer regions II and II' of the detector system 5, of less interest for obtaining measured data, are each connected only to two electronic elements 13. Missing measured values are interpolated by the computer 11 from the existing measured values from the relevant regions, or are extrapolated from the measured values from region I. The data obtained in this way are then processed by the computer 11 in accordance with the usual image reconstruction methods.

As can also be seen from figs. 2 to 4, in this exemplary embodiment the detector elements of a detector column have different longitudinal extents in the z-direction. In the example, these are:

5 mm – 2.5 mm – 1.5 mm – 1 mm –1 mm –1.5 mm – 2.5 mm - 5 mm

Then, by combining the 1.5 mm elements with the 1 mm elements by means of the summation elements 14 in the way illustrated in fig. 2, and by inserting the outer 5 mm elements by means of the beam apertures 15, with this detector system the following mode with 6 lines is also possible, for example for the especially relevant region I that can be seen from fig. 4:

2.5 mm – 2.5 mm – 2.5 mm –2.5 mm – 2.5 mm – 2.5 mm

The invention is not restricted to the exemplary embodiment illustrated, but can be used for multi-line detector systems with any desired number of detector lines and detector columns. In addition, the length of the detector elements in the z-direction can deviate from the exemplary embodiment illustrated within the context of the invention. In particular, the invention also covers detector systems with the same longitudinal extent of the detector elements in the z-direction.

The exemplary embodiment described above is a CT device of the third generation, i.e. the X-ray source and the detector rotate jointly about the system axis during the generation of an image. However, the invention can also be used in CT devices of the fourth generation, in which only the X-ray source rotates and co-operates with a stationary detector ring.

The exemplary embodiment described above relates to the medical application of a CT device according to the invention. However, the invention can also be applied outside medicine, for example in luggage testing or in material examination.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

10/048052
JC13 Rec'd PCT/PTO 25 JAN 2002

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

SUBMISSION OF DRAWINGS FOR PUBLICATION

APPLICANTS:	Flohr et al.
ATTORNEY DOCKET NO.	P02,0001
INTERNATIONAL APPLICATION NO:	PCT/DE00/02438
INTERNATIONAL FILING DATE:	July 25, 2000
INVENTION:	"COMPUTED TOMOGRAPHY DEVICE WITH A MULTI-LINE DETECTOR SYSTEM" (AS AMENDED)

Assistant Commissioner for Patents,

Washington, D.C. 20231

S I R:

Applicants herewith submit two sheets (Figs. 1-4) of drawings in a form suitable for publication.

Submitted by,

Steven H. Noll (Reg. 28,982)

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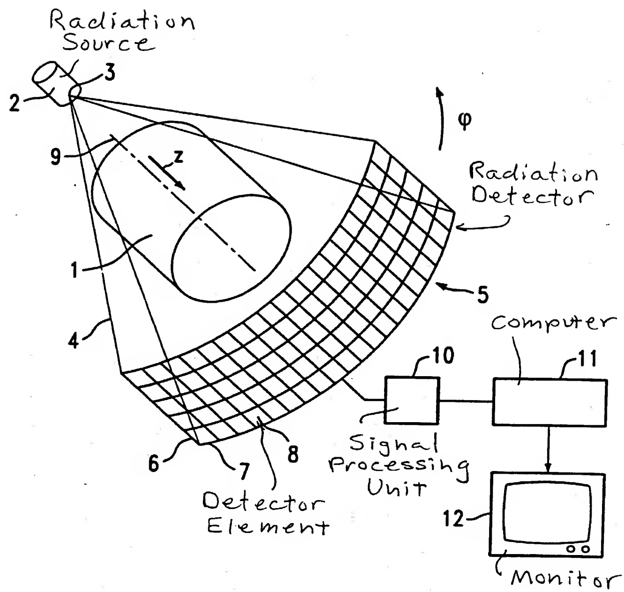
Radiation Source
3
2
9
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Radiation Detector
1
5
4
Computer
10
11
6
7
8
Signal Processing Unit
Detector Element
12
Monitor

FIG 1

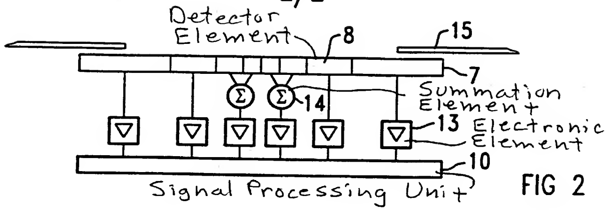

FIG 2

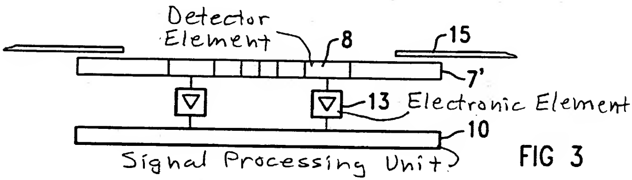

FIG 3

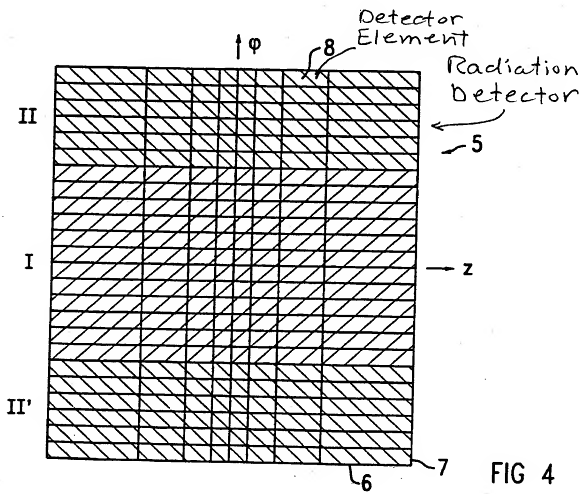

FIG 4

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SPECIFICATION

TITLE

"COMPUTED TOMOGRAPHY DEVICE WITH A MULTI-LINE DETECTOR SYSTEM"

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a CT ([computer] computed tomography) device of the type having a radiation source which, in order to scan an object to be examined, can be displaced [about] relative to a system axis and emits a beam of radiation, which strikes a detector system [comprising] formed by an array of [a plurality of] lines and [a plurality of] columns of detector elements, the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer, which uses them to calculate images of the object to be examined, the signals generated in the detector elements by radiation being supplied to electronic elements to be read and amplified, the number of detector elements of the detector system exceeding the number of electronic elements.

Description of the Prior Art

CT devices are known which have a radiation source, for example an X-ray tube, which [direct] directs a collimated, pyramidal beam of radiation through the object to be examined, for example a patient, onto a detector system [built up from a plurality] formed by a number of detector elements. The radiation source and, depending on the design of the CT device, the detector system also are [fitted] mounted to a gantry, which rotates [about] around the object to be examined. A mounting device for the object to be examined can be displaced or moved along the system axis relative to the gantry. The position from which the radiation beam [of radiation] passes through the object to be examined, and the angle at which the beam of

radiation passes through the object to be examined, are varied continually as a result of the rotation of the gantry. Each detector element in the detector system that is affected by the radiation produces a signal which constitutes a measure of the overall transparency of the object to be examined for the radiation originating from the radiation source on its path to the detector system. The set of output signals from the detector elements of the detector system, which is obtained for a specific position of the radiation source, is referred to as a projection. A scan [comprises] is formed by a set of projections, which have been obtained at various positions of the gantry and/or various positions of the mounting device. During one scan, the CT device assumes a large number of projections, in order to be able to build up a two-dimensional sectional image of a layer of the object to be examined. With a detector system constructed from an array of [a plurality of] lines and columns of detector elements, a [plurality] number of layers can be recorded at the same time.

[DE] German OS 195 02 574 [A1]discloses a CT device of the type mentioned in the introduction having a multi-line detector system, in which, in order to save cost and in order to limit the data rates, the read electronics connected downstream of the detector elements [no longer provide] does not have an electronic element for each detector element. Instead, the number of detector lines exceeds the number of lines of electronic elements. Each line of electronic elements can [therefore] be associated with a [plurality] number of detector lines via multiplexers and summers.

In [the case of the] this known CT device, [it proves to be disadvantageous] a disadvantage is that, [either] as a result of connecting adjacent detector lines together, the thickness of the layers recorded increases, and therefore the resolution in the z-direction [falls, or] is decreased. Another disadvantage is that each detector line is not connected to a line of electronic elements, and therefore it is [no longer] not possible for the entire detector width in the z-direction to be used for data acquisition.

[DE] German OS 198 35 873 [A1] discloses a CT device of the type mentioned in the introduction, in which the number of detector elements exceeds the number of electronic elements and, therefore, region by region, a [plurality] number of detector elements of a detector line are coupled, [that is to say] i.e., are connected to one electronic element, with the coupling of detector elements being omitted in the central region of the detector lines.

SUMMARY OF THE INVENTION

[The] An object of the present invention is [therefore based on the object of improving] to provide a CT device of the type mentioned in the introduction [to the effect that] wherein, in spite of a reduced number of electronic elements, as compared with the number of detector elements, a high resolution can be achieved with the detector system and, nevertheless, a high number of individual layers can be recorded at the same time.

According to the invention, this object is achieved by a CT device having a radiation source which, in order to scan an object to be examined, can be displaced [about] relative to a system axis and emits a radiation beam [of radiation], which strikes a detector system [comprising] formed by an array of [a plurality of] lines and [a plurality of] columns of detector elements, the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer, which uses them to calculate images of the object to be examined, signals generated in the detector elements by radiation being supplied to electronic elements to be read and amplified, the number of detector elements of the detector system exceeding the number of electronic elements, and [it being possible for] wherein a region of detector columns [comprising] including at least one detector column [to] can be connected to a larger number of electronic elements, in order to read out the detector elements from this region, than is a different region [comprising] having the same number of detector columns.

The CT device according to the invention therefore [provides] not only has the advantage that the detector system can be implemented more simply and less expensively by means of the number of electronic elements being reduced with respect to the number of detector elements, but [that] also, therefore, region by region a larger number of layers can be recorded at the same time than in the case of detector systems with a reduced number of electronic elements according to the prior art.

Whereas in [the case of the] known CT devices [previously known], adjacent detector elements can if required be connected together line by line, and each detector column is associated with a permanently predefined number of electronic elements, the detector system according to the invention can be divided into regions with a different resolution both in the z-direction and in the φ-direction. To this end, different detector columns of the detector system according to the invention can be connected to different numbers of electronic elements. If, for example, a CT device according to the prior art has an 8-line detector system with four lines of electronic elements, then each detector column of the detector system is connected to a maximum of four electronic elements. [As distinct from] compared to this, a CT device according to the invention, likewise having an 8-line detector system, permits specific detector columns to be connected, for example, to six electronic elements and other detector columns to be connected only to two electronic elements per detector column. A suitable arrangement of multiplexers and summation elements between the detector elements and the electronic elements permits [the] a largely random interconnection of detector elements and the assignment of individual detector elements or interconnected detector elements to individual electronic elements.

A region of the detector system of the CT device according to the invention whose detector columns are assigned an increased number of electronic elements can, for example, be the [generally] especially relevant central region of the detector system. Outside the central region,

correspondingly fewer measured values are formed as a result of detector elements being combined or not being taken into account. Given the same overall z-length of the collimated layer over the entire detector, many thin individual layers are in this way obtained in one region, but a few wide individual layers in another region. Therefore, in the one region, the number of effective lines, and therefore the resolution in the z-direction, is increased, without additional electronic elements being required for this purpose. In addition, the data rates and amounts of data that can be generated by the detector system do not change with respect to a known detector system having a reduced number of electronic elements.

In the [case of the] CT device according to the invention, the object to be examined can fill the entire measurement field, as hitherto. The object to be examined is merely scanned with a higher resolution in one region than in another region. If the object to be examined fills only a [subregion] portion of the measurement field as, for example, in the case of examinations of internal organs, [of] the head or [of] the extremities of a patient, then the electronic elements of the detector system according to the invention can [advantageously also] be connected to the detector elements [in such a way] so that all the electronic elements are assigned to the relevant region of the detector system, and the edge regions of the detector system, which cannot contribute any measured values to the objects to be displayed, are not assigned any electronic elements. As a result of the simultaneous recording of many thin individual layers, this also leads to an improved resolution with a simultaneous saving in time and costs.

[One] In an embodiment of the invention [provides for] missing measured values from a region with low resolution [to be] are interpolated from the measured values obtained from this region, or missing measured values from a region with a low resolution to be extrapolated from measured values from a region with a high resolution. The values formed in this way,

together with the measured values, can then be supplied to a conventional CT multi-line image reconstruction.

Therefore, in [the case of] this variant, [recourse can substantially be made to] known software can be used in the image reconstruction, which limits the effort and the costs which have to be applied in connection with the creation of the software for a CT device.

[Greater] Larger volumes of an object to be examined are normally registered by means of sequential scanning or spiral scanning. The CT device according to the invention can advantageously be used for both types of scan.

In the case of sequential scanning, the data are recorded during a rotational movement of the gantry, while the object to be examined is located in a fixed position, and therefore a specific number of planar layers are scanned. In order to scan the following layers, the object to be examined is moved into a new position relative to the gantry. This procedure is continued until the volume defined before the examination has been scanned.

In the case of spiral scanning, the gantry with the X-ray radiation source rotates [about] around the object to be examined, while the mounting table and the gantry are displaced continuously relative to each other along a system axis. The radiation source therefore describes a spiral path in relation to the object to be examined, until the volume defined before the examination has been scanned. Images of individual layers are then calculated from the spiral data obtained in this way.

The detector system of the CT device according to the invention may be constructed in a simple and cost-effective way as a modification (retrofit) of conventional detector systems. By means of the arrangement of summation elements and multiplexers between the detector elements and the electronic elements, and the corresponding wiring, the electronic elements are supplied the charges generated by absorption of radiation in the detector elements, to be read and amplified.

In a preferred embodiment of the detector system according to the invention, the length of the detector elements is different in the direction of the system axis (z-direction). In addition to the advantages already mentioned of a detector system according to the invention, this provides the further advantage that, region by region, by means of appropriate interconnection of adjacent detector elements, additional operating modes are therefore possible with this detector system. For example, in the case of an 8-line detector system having the following detector elements which are not equidistant in the z-direction:

5 mm – 2.5 mm – 1.5 mm – 1 mm – 1 mm – 1.5 mm – 2.5 mm – 5 mm

by means of partial insertion of outer detector elements and combination, the following modes can additionally be realized region by region, in which six layers are scanned:

Mode 1: 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm
Mode 2: 1 mm – 1.5 mm – 1 mm – 1 mm – 1.5 mm – 1 mm

[The invention is explained in more detail below using an exemplary embodiment illustrated in the drawing, in which:

Fig. 1 shows the significant parts of an X-ray computer tomograph according to the invention,

Figs. 2 and 3 each show one column of the detector system of the CT device according to fig. 1, with the electronic elements associated with the detector elements of the column, and

Fig. 4 shows a view of the detector system of the CT device according to fig. 1, from which the arrangement of the columns according to figs. 2 and 3 can be seen.]

DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the basic components of an X-ray computed tomography device constructed and operating in accordance with the present invention.

Figure 2 shows one column in a central region of the detector system of the computed tomography device of Figure 1, showing how the electronic components are associated with the detector elements of the column.

Figure 3 shows one column in a outer region of the detector system of the computed tomography device of Figure 1, showing how the electronic components are associated with the detector elements of the column.

Figure 4 is a plan view of the detector system of the computed tomography device according to Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a CT device which is provided [in order to scan] for scanning an object 1 to be examined and which has a radiation source 2, for example an X-ray tube, with a focus 3 from which a pyramidal beam 4 of radiation collimated by a radiation [aperture] diaphragm (not illustrated) originates, passes through the object 1 to be examined, for example a patient, and strikes a detector system 5.

The latter has an array [comprising a plurality] of [mutually] parallel lines 6 and [a plurality of mutually] parallel columns 7 of detector elements 8. The radiation source 2 and the detector system 5 form a measuring system, which can be displaced in the φ-direction [about] around a system axis 9 and can be displaced along the system axis relative to the object 1 to be examined, so that the object 1 to be examined is irradiated at various projection angles and various z-positions along the system axis 9. From the output signals which occur in the process from the detector elements 8 of the

detector system 5, a signal processing unit 10 forms measured values, which are supplied to a computer 11, which calculates an image of the object 1 to be examined, which is reproduced on a monitor 12.

In [fig.] Fig. 1, the detector system 5 is shown only [roughly] schematically with a number of lines and columns that differs from [figs] Figs. 2 to 4. Figures 2 to 4 show that, in the case of the exemplary embodiment described, the detector system has eight lines 6 and twenty-four columns 7, the length of the detector elements 8 in the z-direction, that is to say in the direction of the system axis 9, not being the same for all lines. By means of appropriate insertion and combination of detector lines 6, this geometry is very flexible in the selection of the layer thicknesses to be scanned of the object to be examined. In the middle, each column 7 of the detector system 5 is assigned four electronic elements 13 to read out and amplify the charges generated in the detector elements 8 by the absorption of X radiation. The association between an electronic element 13 and one or more detector elements 8 is carried out via summation elements 14 and multiplexers (not illustrated). The signals registered by the electronic elements 13 are supplied to a signal processing unit 10 for further processing.

As [fig.] Fig. 2 reveals, the eight detector elements 8 of the detector column 7 illustrated, which, according to fig. 4, lies in the central region of the detector system 5 in the φ-direction, are connected to six electronic elements 13, of the central four detector elements, in each case two, combined via a summation element 14, being connected to one electronic element 13. Signals from all the detector elements in this detector column are thus registered and supplied to the signal processing unit 10.

In order on average to achieve the assignment of four electronic elements per detector column, eight detector elements from another detector column 7', shown in fig. 3, are assigned only two electronic elements 13. The detector column 7' in this case lies in the outer region of the detector system 5 in the φ-direction, according to fig. 4.

Measured values which are missing as compared with the detector column 7 according to [fig.] Fig. 2 are interpolated from the measured values obtained with the detector column 7' and/or extrapolated from the measured values from adjacent detector columns by means of the computer 11. Therefore, for further signal processing, recourse can be made to image reconstruction algorithms already implemented.

Fig. 4 [reveals] shows the division of the exemplary detector system 5 into eight lines 6 and twenty-four columns 7 of detector elements 8 in each case. If, for example, only a section of the object 1 to be examined is to be examined, for example in order to image internal organs, the head or the extremities of a patient, then given appropriate positioning of the object 1 to be examined in the CT device, one subregion of the detector system 5 is particularly relevant for registering measured values. In the example according to fig. 4, this is assumed to be the central region I of the detector system 5, [comprising] containing twelve columns 7 of detector elements 8. In order to increase the resolution in this particularly relevant measurement region, the detector columns 7 according to fig. 2 are each connected to six electronic elements 13. In order to compensate, the columns 7 from the outer regions II and II' of the detector system 5, of less interest for obtaining measured data, are each connected only to two electronic elements 13. Missing measured values are interpolated by the computer 11 from the existing measured values from the relevant regions, or are extrapolated from the measured values from region I. The data obtained in this way are then processed by the computer 11 in accordance with the usual image reconstruction methods.

As can also be seen from figs. 2 to 4, in this exemplary embodiment the detector elements of a detector column have different longitudinal extents in the z-direction. In the example, these are:

5 mm – 2.5 mm – 1.5 mm – 1 mm –1 mm –1.5 mm – 2.5 mm - 5 mm

Then, by combining the 1.5 mm elements with the 1 mm elements by means of the summation elements 14 in the way illustrated in fig. 2, and by inserting the outer 5 mm elements by means of the beam apertures 15, with this detector system the following mode with 6 lines is also possible, for example for the especially relevant region I that can be seen from fig. 4:

2.5 mm – 2.5 mm – 2.5 mm –2.5 mm – 2.5 mm – 2.5 mm

The invention is not restricted to the exemplary embodiment illustrated, but can be used for multi-line detector systems with any desired number of detector lines and detector columns. In addition, the length of the detector elements in the z-direction can deviate from the exemplary embodiment illustrated within the context of the invention. In particular, the invention also covers detector systems with the same longitudinal extent of the detector elements in the z-direction.

The exemplary embodiment described above is a CT device of the third generation, [that is to say] i.e. the X-ray source and the detector rotate jointly about the system axis during the generation of an image. However, the invention can also be used in CT devices of the fourth generation, in which only the X-ray source rotates and co-operates with a stationary detector ring.

The exemplary embodiment described above relates to the medical application of a CT device according to the invention. However, the invention can also be applied outside medicine, for example in luggage testing or in material examination.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

10/048052
JC13 Rec'd PCT/PTO 25 JAN 2002

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

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UNDER THE PATENT COOPERATION TREATY-CHAPTER II

REQUEST FOR APPROVAL OF DRAWING CHANGES

APPLICANTS:	Flohr et al.
ATTORNEY DOCKET NO.	P02,0001
INTERNATIONAL APPLICATION NO:	PCT/DE00/02438
INTERNATIONAL FILING DATE:	July 25, 2000
INVENTION:	"COMPUTED TOMOGRAPHY DEVICE WITH A MULTI-LINE DETECTOR SYSTEM" (AS AMENDED)

Assistant Commissioner for Patents,

Washington, D.C.

S I R:

Applicants herewith request approval of the drawing changes in each of Figures 1, 2 and 3, as shown on the drawing copies marked in red attached hereto.

Submitted by,

Steven H. Noll (Reg. 28,982)

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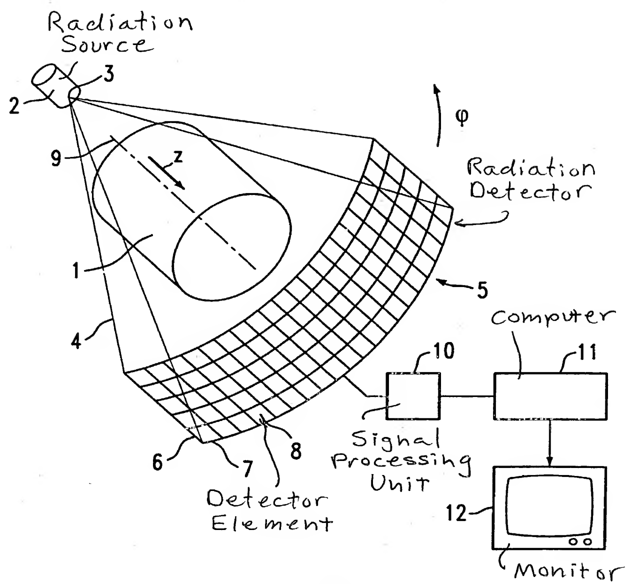
Radiation Source
3
2
φ
9
z
Radiation Detector
1
5
Computer
4
10
11
Signal Processing Unit
8
6
7
Detector Element
12
Monitor

FIG 1

2/2

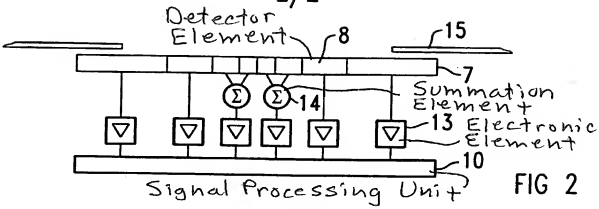

FIG 2

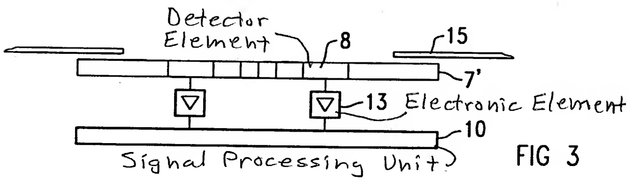

FIG 3

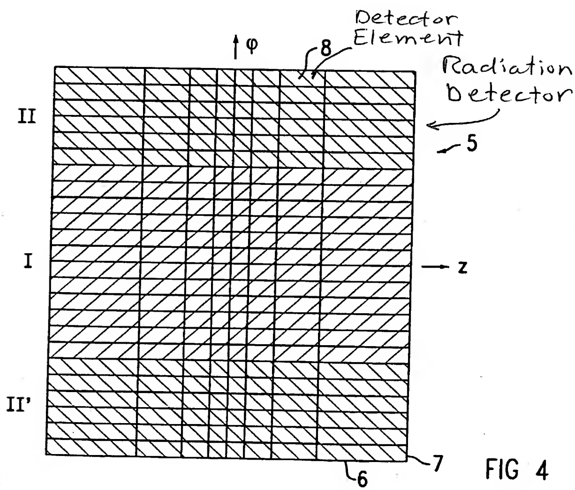

FIG 4

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Description

CT device with a multi-line detector system

The invention relates to a CT (computer tomography) device having a radiation source which, in order to scan an object to be examined, can be displaced about a system axis and emits a beam of radiation, which strikes a detector system comprising an array of a plurality of lines and a plurality of columns of detector elements, the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer, which uses them to calculate images of the object to be examined, signals generated in the detector elements by radiation being supplied to electronic elements to be read and amplified, the number of detector elements of the detector system exceeding the number of electronic elements.

CT devices are known which have a radiation source, for example an X-ray tube, which direct a collimated, pyramidal beam of radiation through the object to be examined, for example a patient, onto a detector system built up from a plurality of detector elements. The radiation source and, depending on the design of the CT device, the detector system also are fitted to a gantry, which rotates about the object to be examined. A mounting device for the object to be examined can be displaced or moved along the system axis relative to the gantry. The position from which the beam of radiation passes through the object to be examined, and the angle at which the beam of radiation passes through the object to be examined, are varied continually as a result of the rotation of the gantry. Each detector element in the detector system that is affected by the radiation produces a signal which constitutes a measure of the overall transparency of the object to be examined for the radiation originating from the radiation source on its path to the detector system. The set of output signals from the detector elements of the detector system, which is obtained for a specific position of the

radiation source, is referred to as a projection. A scan comprises a set of projections, which have been obtained at various positions of the gantry and/or various positions of the mounting device. During one scan, the CT device assumes a large number of projections, in order to be able to build up a two-dimensional sectional image of a layer of the object to be examined. With a detector system constructed from an array of a plurality of lines and columns of detector elements, a plurality of layers can be recorded at the same time.

DE-195 02 574 A1 discloses a CT device of the type mentioned in the introduction having a multi-line detector system, in which in order to save cost and in order to limit the data rates, the read electronics connected downstream of the detector elements no longer provide an electronic element for each detector element. Instead, the number of detector lines exceeds the number of lines of electronic elements. Each line of electronic elements can therefore be associated with a plurality of detector lines via multiplexers and summers.

In the case of the known CT device, it proves to be disadvantageous that, either as a result of connecting adjacent detector lines together, the thickness of the layers recorded increases, and therefore the resolution in the z-direction falls, or that each detector line is not connected to a line of electronic elements, and therefore it is no longer possible for the entire detector width in the z-direction to be used for data acquisition.

DE 198 35 873 A1 discloses a CT device of the type mentioned in the introduction, in which the number of detector elements exceeds the number of electronic elements and, therefore, region by region, a plurality of detector elements of a detector line are coupled, that is to say are connected to one

electronic element, the coupling of detector elements being omitted in the central region of the detector lines.

The present invention is therefore based on the object of improving a CT device of the type mentioned in the introduction to the effect that, in spite of a reduced number of electronic elements, as compared with the number of detector elements, a high resolution can be achieved with the detector system and, nevertheless, a high number of individual layers can be recorded at the same time.

According to the invention, this object is achieved by a CT device having a radiation source which, in order to scan an object to be examined, can be displaced about a system axis and emits a beam of radiation, which strikes a detector system comprising an array of a plurality of lines and a plurality of columns of detector elements, the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer, which uses them to calculate images of the object to be examined, signals generated in the detector elements by radiation being supplied to electronic elements to be read and amplified, the number of detector elements of the detector system exceeding the number of electronic elements, and it being possible for a region of detector columns comprising at least one detector column to be connected to a larger number of electronic elements in order to read out the detector elements from this region than a different region comprising the same number of detector columns.

The CT device according to the invention therefore provides not only the advantage that the detector system can be implemented more simply and less expensively by means of the number of electronic elements being reduced with respect to the number of detector elements, but that, therefore,

region by region a larger number of layers can be recorded at the same time than in the case of detector systems with a reduced number of electronic elements according to the prior art.

Whereas in the case of the CT devices previously known, adjacent detector elements can if required be connected together line by line, and each detector column is associated with a permanently predefined number of electronic elements, the detector system according to the invention can be divided into regions with a different resolution both in the z-direction and in the φ-direction. To this end, different detector columns of the detector system according to the invention can be connected to different numbers of electronic elements. If, for example, a CT device according to the prior art has an 8-line detector system with four lines of electronic elements, then each detector column of the detector system is connected to a maximum of four electronic elements. As distinct from this, a CT device according to the invention, likewise having an 8-line detector system, permits specific detector columns to be connected, for example, to six electronic elements and other detector columns to be connected only to two electronic elements per detector column. A suitable arrangement of multiplexers and summation elements between the detector elements and the electronic elements permits the largely random interconnection of detector elements and the assignment of individual detector elements or interconnected detector elements to individual electronic elements.

A region of the detector system of the CT device according to the invention whose detector columns are assigned an increased number of electronic elements can, for example, be the generally especially relevant central region of the detector system. Outside the central region, correspondingly fewer measured values are formed as a result of detector elements being combined or not being taken into account. Given the same overall z-length

of the collimated layer over the entire detector, many thin individual layers are in this way obtained in one region, but a few wide individual layers in another region. Therefore, in the one region, the number of effective lines and therefore the resolution in the z-direction is increased, without additional electronic elements being required for this purpose. In addition, the data rates and amounts of data that can be generated by the detector system do not change with respect to a known detector system having a reduced number of electronic elements.

In the case of the CT device according to the invention, the object to be examined can fill the entire measurement field, as hitherto. The object to be examined is merely scanned with a higher resolution in one region than in another region. If the object to be examined fills only a subregion of the measurement field, for example, in the case of examinations of internal organs, of the head or of the extremities of a patient, then the electronic elements of the detector system according to the invention can advantageously also be connected to the detector elements in such a way that all the electronic elements are assigned to the relevant region of the detector system, and the edge regions of the detector system, which cannot contribute any measured values to the objects to be displayed, are not assigned any electronic elements. As a result of the simultaneous recording of many thin individual layers, this also leads to an improved resolution with a simultaneous saving in time and costs.

One embodiment of the invention provides for missing measured values from a region with low resolution to be interpolated from the measured values obtained from this region, or missing measured values from a region with a low resolution to be extrapolated from measured values from a region with a high resolution. The values formed in this way, together with the measured

values, can then be supplied to a conventional CT multi-line image reconstruction.

Therefore, in the case of this variant, recourse can substantially be made to known software in the image reconstruction, which limits the effort and the costs which have to be applied in connection with the creation of the software for a CT device.

Greater volumes of an object to be examined are normally registered by means of sequential scanning or spiral scanning. The CT device according to the invention can advantageously be used for both types of scan.

In the case of sequential scanning, the data are recorded during a rotational movement of the gantry, while the object to be examined is located in a fixed position, and therefore a specific number of planar layers are scanned. In order to scan the following layers, the object to be examined is moved into a new position relative to the gantry. This procedure is continued until the volume defined before the examination has been scanned.

In the case of spiral scanning, the gantry with the X-ray radiation source rotates about the object to be examined, while the mounting table and the gantry are displaced continuously relative to each other along a system axis. The radiation source therefore describes a spiral path in relation to the object to be examined, until the volume defined before the examination has been scanned. Images of individual layers are then calculated from the spiral data obtained in this way.

The detector system of the CT device according to the invention may be constructed in a simple and cost-effective way as a modification of conventional detector systems. By means of the arrangement of summation elements and multiplexers between the detector elements and the electronic elements, and the corresponding wiring, the electronic elements are supplied the charges generated by absorption of radiation in the detector elements, to be read and amplified.

In a preferred embodiment of the detector system according to the invention, the length of the detector elements is different in the direction of the system axis (z-direction). In addition to the advantages already mentioned of a detector system according to the invention, this provides the further advantage that, region by region, by means of appropriate interconnection of adjacent detector elements, additional operating modes are therefore possible with this detector system. For example, in the case of an 8-line

detector system having the following detector elements which are not equidistant in the z-direction:

5 mm – 2.5 mm – 1.5 mm – 1 mm – 1 mm – 1.5 mm – 2.5 mm – 5 mm by means of partial insertion of outer detector elements and combination, the following modes can additionally be realized region by region, in which six layers are scanned:

Mode 1: 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm – 2.5 mm
Mode 2: 1 mm – 1.5 mm – 1 mm – 1 mm – 1.5 mm – 1 mm

The invention is explained in more detail below using an exemplary embodiment illustrated in the drawing, in which:

Fig. 1 shows the significant parts of an X-ray computer tomograph according to the invention,

Figs. 2 and 3 each show one column of the detector system of the CT device according to fig. 1, with the electronic elements associated with the detector elements of the column, and
Fig. 4 shows a view of the detector system of the CT device according to fig. 1, from which the arrangement of the columns according to figs. 2 and 3 can be seen.

Fig. 1 shows a CT device which is provided in order to scan an object 1 to be examined and which has a radiation source 2, for example an X-ray tube, with a focus 3 from which a pyramidal beam 4 of radiation collimated by a radiation aperture (not illustrated) originates, passes through the object 1 to be examined, for example a patient, and strikes a detector system 5.

The latter has an array comprising a plurality of mutually parallel lines 6 and a plurality of mutually parallel columns 7 of detector elements 8. The radiation source 2 and the detector system 5 form a measuring system, which can be displaced in the φ-direction about a system axis 9 and can be displaced along the system axis relative to the object 1 to be examined, so that the object 1 to be examined is irradiated at various projection angles and various z-positions along the system axis 9. From the output signals which occur in the process from the detector elements 8 of the detector system 5, a signal processing unit 10 forms measured values, which are supplied to a computer 11, which calculates an image of the object 1 to be examined, which is reproduced on a monitor 12.

In fig. 1, the detector system 5 is shown only roughly schematically with a number of lines and columns that differs from figs. 2 to 4. Figures 2 to 4 show that, in the case of the exemplary embodiment described, the detector system has eight lines 6 and twenty-four columns 7, the length of the detector elements 8 in the z-direction, that is to say in the direction of the system axis 9, not being the same for all lines. By means of appropriate insertion and combination of detector lines 6, this geometry is very flexible in the selection of the layer thicknesses to be scanned of the object to be examined. In the middle, each column 7 of the detector system 5 is assigned four electronic elements 13 to read out and amplify the charges generated in the detector elements 8 by the absorption of X radiation. The association between an electronic element 13 and one or more detector elements 8 is carried out via summation elements 14 and multiplexers (not illustrated). The signals registered by the electronic elements 13 are supplied to a signal processing unit 10 for further processing.

As fig. 2 reveals, the eight detector elements 8 of the detector column 7 illustrated, which, according to fig. 4, lies in the central region of the detector

system 5 in the φ-direction, are connected to six electronic elements 13, of the central four detector elements, in each case two, combined via a summation element 14, being connected to one electronic element 13. Signals from all the detector elements in this detector column are thus registered and supplied to the signal processing unit 10.

In order on average to achieve the assignment of four electronic elements per detector column, eight detector elements from another detector column 7', shown in fig. 3, are assigned only two electronic elements 13. The detector column 7' in this case lies in the outer region of the detector system 5 in the φ-direction, according to fig. 4.

Measured values which are missing as compared with the detector column 7 according to fig. 2 are interpolated from the measured values obtained with the detector column 7' and/or extrapolated from the measured values from adjacent detector columns by means of the computer 11. Therefore, for further signal processing, recourse can be made to image reconstruction algorithms already implemented.

Fig. 4 reveals the division of the exemplary detector system 5 into eight lines 6 and twenty-four columns 7 of detector elements 8 in each case. If, for example, only a section of the object 1 to be examined is to be examined, for example in order to image internal organs, the head or the extremities of a patient, then given appropriate positioning of the object 1 to be examined in the CT device, one subregion of the detector system 5 is particularly relevant for registering measured values. In the example according to fig. 4, this is assumed to be the central region I of the detector system 5, comprising twelve columns 7 of detector elements 8. In order to increase the resolution in this particularly relevant measurement region, the detector columns 7 according to fig. 2 are each connected to six electronic elements 13. In

order to compensate, the columns 7 from the outer regions II and II' of the detector system 5, of less interest for obtaining measured data, are each connected only to two electronic elements 13. Missing measured values are interpolated by the computer 11 from the existing measured values from the relevant regions, or are extrapolated from the measured values from region I. The data obtained in this way are then processed by the computer 11 in accordance with the usual image reconstruction methods.

As can also be seen from figs. 2 to 4, in this exemplary embodiment the detector elements of a detector column have different longitudinal extents in the z-direction. In the example, these are:

5 mm – 2.5 mm – 1.5 mm – 1 mm –1 mm –1.5 mm – 2.5 mm - 5 mm

Then, by combining the 1.5 mm elements with the 1 mm elements by means of the summation elements 14 in the way illustrated in fig. 2, and by inserting the outer 5 mm elements by means of the beam apertures 15, with this detector system the following mode with 6 lines is also possible, for example for the especially relevant region I that can be seen from fig. 4:

2.5 mm – 2.5 mm – 2.5 mm –2.5 mm – 2.5 mm – 2.5 mm

The invention is not restricted to the exemplary embodiment illustrated, but can be used for multi-line detector systems with any desired number of detector lines and detector columns. In addition, the length of the detector elements in the z-direction can deviate from the exemplary embodiment illustrated within the context of the invention. In particular, the invention also covers detector systems with the same longitudinal extent of the detector elements in the z-direction.

The exemplary embodiment described above is a CT device of the third generation, that is to say the X-ray source and the detector rotate jointly about the system axis during the generation of an image. However, the invention can also be used in CT devices of the fourth generation, in which only the X-ray source rotates and co-operates with a stationary detector ring. The exemplary embodiment described above relates to the medical application of a CT device according to the invention. However, the invention can also be applied outside medicine, for example in luggage testing or in material examination.

Patent Claims

1. A CT device having a radiation source (2) which, in order to scan an object (1) to be examined, can be displaced about a system axis (9) and emits a beam (4) of radiation, which strikes a detector system (5) comprising an array of a plurality of lines (6) and a plurality of columns (7, 7') of detector elements (8), the measured values obtained in this way being associated with one of a large number of projection angles and being supplied to a computer (11), which uses them to calculate images of the object (1) to be examined, signals generated in the detector elements (8) by radiation being supplied to electronic elements (13) to be read and amplified, the number of detector elements (8) of the detector system (5) exceeding the number of electronic elements (13), and it being possible for a region detector columns (7) comprising at least one detector column (7) to be connected to a larger number of electronic elements (13) in order to read out the detector elements (8) from this region than a different region comprising the same number of detector columns (7).

2. The CT device with a detector system (5) as claimed in claim 1, in which detector elements (8) of a region comprising at least one detector column (7) are not connected to electronic elements (13).

3. The CT device with a detector system (5) as claimed in claim 1 or 2, in which missing measured values from the region (II, II') with a reduced number of associated electronic elements (13) can be determined by interpolation of the measured values obtained from this region (II, II') and/or extrapolation of the measured values from the region (I) with an increased number of associated electronic elements (13).

4. The CT device with a detector system (5) as claimed in one or more of claims 1 to 3, in which a mounting device for the object (1) to be examined and the radiation source (2) can be adjusted relative to each other in the direction of the system axis (9), and the measured values obtained are associated with a z-position on the system axis (9).

5. The CT device with a detector system (5) as claimed in one or more of claims 1 to 4, in which charges produced in the detector elements (8) by absorption of radiation are supplied to electronic elements (13) to be read and amplified.

6. The CT device with a detector system (5) as claimed in one or more of claims 1 to 5, in which, at least in two detector lines (6), the length of the detector elements (8) is different in the direction of the system axis (9).

Abstract

CT device with a multi-line detector system

In a CT device with a multi-line detector system (5), different columns (7, 7') of the detector system (5) can be connected to different numbers of electronic elements (13) in order to read the signals generated in the detector elements (8). Thus, by using the detector systems (5), regions of the object to be examined can be scanned with a high resolution, and other regions can be scanned with a lower resolution. A high resolution in regions can therefore be achieved with a simplified and less expensive detector system (5), which generates a comparatively low data rate and amount of data.

Figure 4

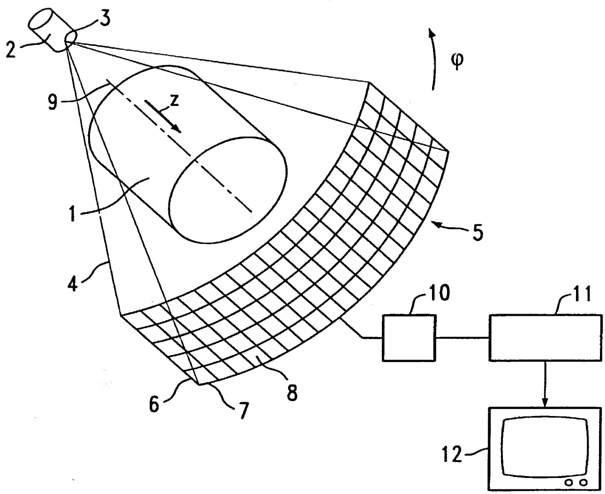

FIG 1

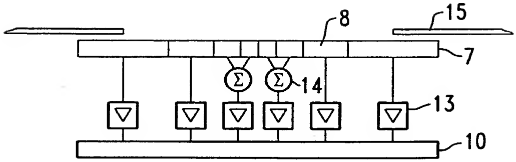

FIG 2

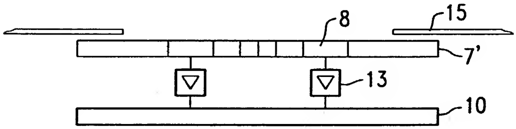

FIG 3

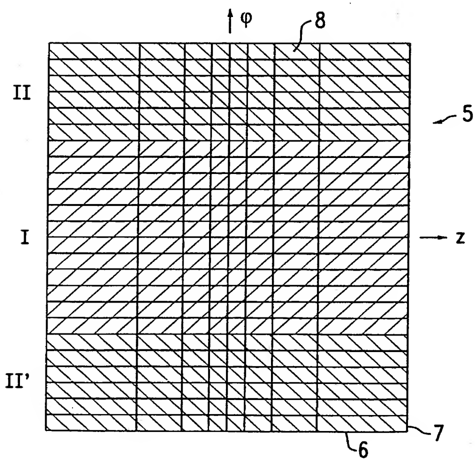

FIG 4

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NUMBER P02,0001

#4.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

"COMPUTED TOMOGRAPHY DEVICE WITH A MULTI-LINE DETECTOR SYSTEM" (AS AMENDED)

the specification of which (check only one item below):

□ is attached hereto.

■ was filed as United States application Serial No. 10/048,052

on January 25, 2002,

and was amended

on January 25, 2002 (if applicable).

□ was filed as PCT international application

Number ____

on ____,

and was amended under PCT Article 19

on ____ (if applicable).

I hereby state that I have reviewed and understand the contest of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (If PCT indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Germany	199 35 093.0	27.07.1999	■ YES □ NO
			□ YES □ NO
			□ YES □ NO
			□ YES □ NO
			□ YES □ NO

Combined Declaration For Patent Application and Power of Attorney (Continued) (Includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NO. P02,0001

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT International application(s) designating the United States of America that is/are listed below and, insofar as the subject mater of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT International filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS			STATUS (Check one)		
U.S. APPLICATION NUMBER		U.S. FILING DATE	PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)			

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected herewith.

And I hereby appoint all Attorneys identified by the United States Patent & Trademark Office Customer Number 26574, who are all members of the firm of Schiff, Hardin & Waite.

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	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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Thomas Flohr	Bernd	
DATE 04/07/02	DATE 04/07/02	DATE